PATTERNS IN THE ACTIVITY OF THE MILLIPEDE *OMMATOIULUS MORELETI* (DIPLOPODA: JULIDAE)

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Abstract

The millipede *Ommatoiulus moreleti* (Lucas) is a nuisance pest in southern Australia, especially during autumn and spring when large numbers invade houses. In a residential area of the Mt Lofty Ranges, South Australia, both male and female *O. moreleti* (stadium 6 and older) were primarily nocturnal. There was no variation in activity rhythm with stadial age. In a woodland of *Eucalyptus* spp. and on a house driveway, active male millipedes were scarce relative to females in late summer. In autumn, active males outnumbered females. This change may be related to sexual differences in climatic tolerance. In the oldest adult stadia, active males were rarer than females. This may be explained by poorer survivorship of males rather than sexual differences in activity. Local council records of applications for pesticide to combat millipedes suggested a close relationship between the eruption of activity and the onset of rains in late summer and early autumn. However, no obvious association between applications for pesticide and prevailing weather was apparent in spring.

Introduction

The introduced Portuguese millipede, *Ommatoiulus moreleti* (Lucas) is a significant nuisance pest in southern Australia, entering houses in large numbers especially during autumn and to a lesser extent in spring (Baker 1978a). Various aspects of the biology of *O. moreleti* have been studied (Baker 1978a,b,c, 1979a,b, 1980, 1984, 1985a,b,c,d, Read 1985, Carey and Bull 1986), either in the laboratory or in grasslands, shrublands and woodlands. However, the biology of *O. moreleti* in and around houses has, largely been ignored.

The life cycle of *O. moreleti* consists of an egg, legless pupoid and then a series of up to 16 stadia (Baker 1978b). Development is anamorphic. The sexes are first distinguishable in stadium 6. Maturity is variable with respect to stadium, but most millipedes observed in grasslands, woodlands and shrublands have been mature by stadia 10 or 11. *O. moreleti* is periodomorphic. Two forms of adult male occur, copulatory and intercalary, which alternate in successive stadia. Intercalary males possess rudimentary gonopods and are incapable of mating. In South Australian grasslands and woodlands, *O. moreleti* breeds during autumn and early winter.

Seasonal changes in the activity of *O. moreleti* have been studied in both Australia and Portugal and related to prevailing weather (Baker 1979b,1984), but diurnal rhythms of activity have not been reported in any detail. During autumn in Portugal, Baker (1984) noted that, whilst weekly pitfall trap catches were dominated by males, a collection of millipedes

found active during the day was mostly made up of females. This suggested a difference between the diurnal activity rhythms of the sexes.

This paper reports on the diurnal rhythms of activity of male and female *O. moreleti* in an urban area of South Australia. Applications by residents to a local council for assistance in millipede control are used to further correlate seasonal eruptions of active millipedes with prevailing weather. Seasonal patterns in the activities of male and female *O. moreleti* in a woodland of *Eucalyptus* spp. are also documented in more detail.

Methods and Study Sites

On five occasions during 1986 and once in 1987, all the millipedes active on a concrete driveway adjacent to a house at Crafers in the Mt Lofty Ranges, South Australia were collected at 2 hourly intervals over a period of 48 hours, commencing at 13:00 h. The time taken for each collection varied from 3 to 20 minutes (one pass over the driveway). The driveway was 4 x 20 m and bordered by pine bark chips and small shrubs. The nearest electric light to the driveway was 15 m from one end. There was no obvious pattern to the distribution of the millipedes on the driveway to suggest any influence from this light. Collections were mostly made in late summer-autumn (February, March (1986 and 1987), April and May) and once during spring (October). Additional collections of millipedes seen active on the driveway between 12:00 and 14:00 h were occasionally made on other days in autumn 1987. These collections took up to one hour and involved several passes over the driveway. Sex and stadium were recorded for all individuals (using the ocular field method to determine stadium) (Baker 1978b). Females were dissected to detect the presence of mature eggs in their ovitubes and males were identified as juvenile, copulatory or intercalary by the morphology of their gonopods.

In a previous study (Baker 1979b), I set 32 pitfall traps in a woodland of *Eucalyptus* spp. (Engelbrook Reserve) at Bridgewater in the Mt Lofty Ranges. I collected *O. moreleti* during 1972 and 1973, usually trapping daily for one week in every five weeks, but occasionally trapping for shorter periods in between. In another study (Baker 1985a, 1986), I also set pitfall traps in the same woodland during 1983 and 1984. These 80 traps were set continuously and emptied weekly. Data on the sex ratios of the millipedes in these traps are presented here.

During the 1970's, the District Council of Stirling in the Mt Lofty Ranges issued free pesticide (carbaryl) to local residents for use against millipedes around their houses. The addresses of the applicants for the pesticide and their dates of application were recorded. These data can be used to show the timing of the onset of the seasonal activity of the millipedes in urban areas and can be correlated with weather data (recorded in Stirling). Some of the data for 1975-79 are presented here.

Note on taxonomy: *O. moreleti* has previously been referred to as *O. moreletii* in Australia following the identification by C.A.W. Jeekel (Amsterdam) for Baker (1978a). Jeekel (1985) has recently corrected the spelling to *O. moreleti*, as used by other European authors (e.g. Read 1985). This name is now used here.

Results

Collections on driveway

The activity of *O. moreleti* on the driveway was primarily nocturnal (Fig. 1). On most occasions, slightly higher numbers of millipedes were collected in the first few hours after sunset compared with other times. Whether this reflects greater activity in the early hours of darkness or greater availability

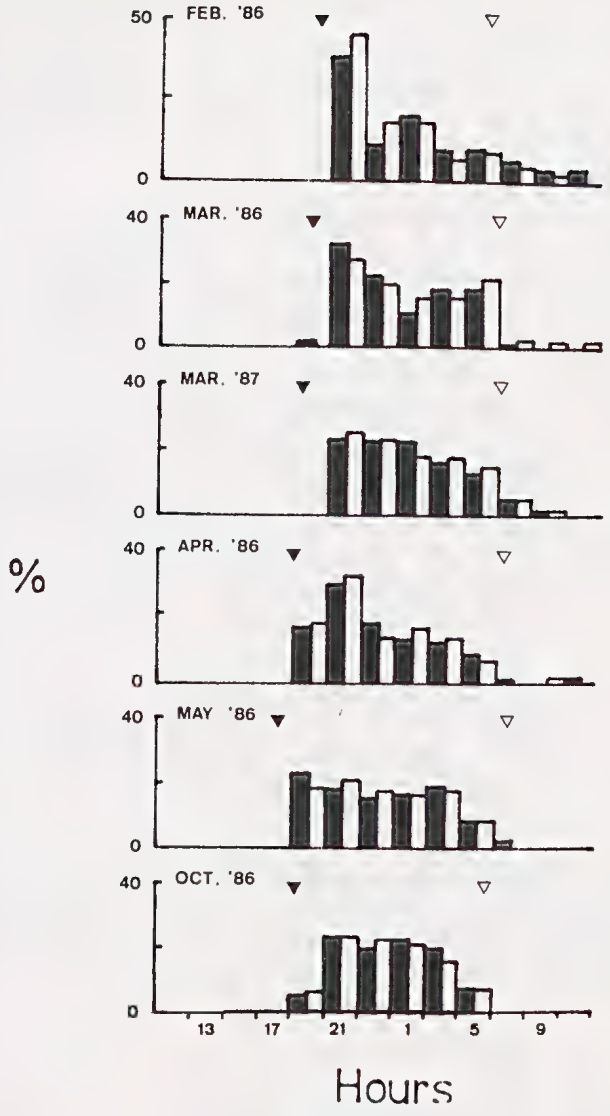

Fig 1. Percentages of the total male (shaded) and female (open) *Ommatoiulus moreleti* collected on the driveway at different times in 1986 and 1987. Data for the two consecutive days of collection are combined. Total numbers of males and females are given in Table 1. Times of sunrise (▽) and sunset (▼) are indicated.

followed by reduced local abundance due to 'trapping out' is not known. However, on occasions when collections took longest (e.g. March 1987 and October 1986) it was obvious at the end of each 2-hourly sampling that the areas of the driveway first collected from (up to 20 minutes earlier) had already been recolonized by immigrants from adjacent garden areas. The numbers present then seemed comparable with the original numbers. This rapid replacement of the removed individuals suggests that 'trapping out' was of negligible importance.

There were no differences in the nocturnal activity patterns of the sexes (Fig. 1). Sex ratios varied between months (Table 1) ($X^2=143.1$, $p < 0.05$); more females were collected in late summer-early autumn and more males in mid-late autumn. There were no differences in the nocturnal activity patterns of the various stadia of *O. moreleti* on the driveway in any month. Table 2 shows data for October 1986 and March 1987 as examples of the stadia collected. No females containing mature eggs were collected in spring (October 1986) (Table 3). In early autumn (March 1987), such females were common (Table 3) and in late autumn (May 1986) they predominated (77.8% of females in stadium 9 and older contained eggs). Most males in spring were juvenile: most males in autumn were copulatory (Table 3). Males and females were collected in similar numbers in the youngest stadia (7 and 8), but relatively few males were found in the oldest stadia. During autumn, males were very much more common than females in stadium 9.

Males predominated when collections were made on the driveway between 1200 and 1400 h in autumn 1987 (Table 4). Most active millipedes were in stadia 9, 10 and 11. These same stadia predominated in the collections made during both day and night on the driveway in autumn (Table 2).

Collections in pitfall traps

The proportions of males in the populations of *O.moreleti* trapped in the woodland of *Eucalyptus* spp. in 1972-73 were low in late summer and high in autumn (Fig.2). In 1983-84, males were as common as females in the traps in the woodland in mid to late autumn but rarer at other times of the year (Fig.3). The proportion of males trapped decreased with increased age (Fig. 4).

Pesticide records

In each year from 1975 to 1979, the numbers of applications for pesticide increased markedly in late February and early March and also in late September (Fig. 5). Similar patterns were observed in areas where the millipede was long-established (e.g. central Bridgewater) and areas near the periphery of the expanding distribution (see Baker 1978a, 1979a, 1985a), suggesting little influence of early application by experienced residents.

Table 1. Numbers of male and female *Ommatoiulus moreleti* on driveway.

Date	Male	Female	Total
February 1986	31	47	78
Early March 1986	80	127	207
Late March 1987	1527	1338	2865
April 1986	186	80	266
May 1986	672	434	1106
October 1986	1514	1813	3327

Table 2 Age distributions of *Ommatoiulus moreleti* on driveway at different times (data for two consecutive days combined)

	Stadia								
Time (h)	6	7	8	9	10	11	12	13	Total
(a) October 1986									
13:00			5	5	2	1			13
15:00			1	1					2
17:00			1	1					2
19:00		8	107	73	15	6	1		210
21:00		29	386	299	51	11	2		778
23:00		27	349	275	56	8			715
01:00		19	354	292	51	6	2		724
03:00		34	291	219	43	13			600
05:00		5	132	98	6	5			246
07:00		2	4	8	2				16
09:00			4	4	4	1			13
11:00		1	3	3	1				8
Total		125	1637	1278	231	51	5		3327
(b) March 1987									
13:00				1	2	1			4
15:00									0
17:00									0
19:00									0
21:00	1	7	11	182	429	145	17	2	794
23:00		14	15	149	329	89	19		615
01:00		9	12	150	266	69	18	7	531
03:00	3	7	16	92	227	73	13		431
05:00		12	6	95	184	61	11		369
07:00			2	11	50	24	5	2	94
09:00				6	8	6	2		22
11:00					2	1	2		5
Total	4	49	62	686	1497	469	87	11	2865

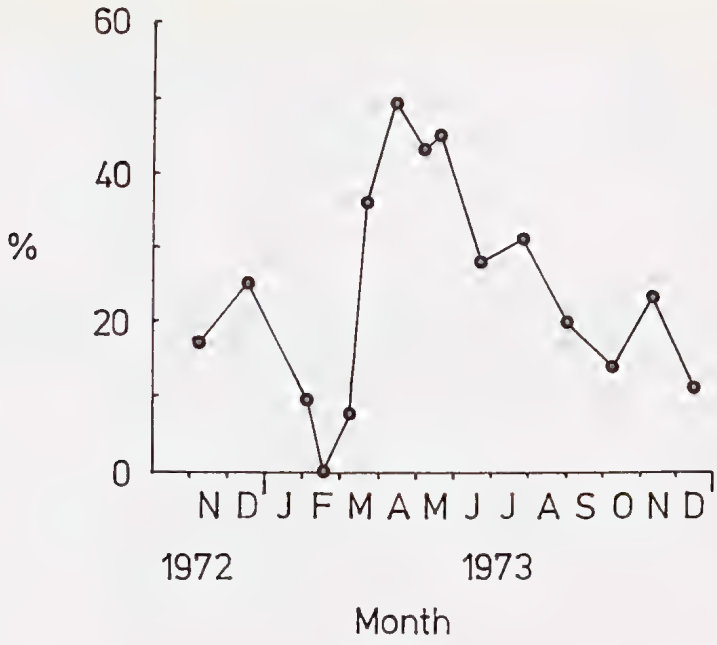

Fig 2. Percentages of males in populations of *Ommatoiulus moreleti* collected in pitfall traps in *Eucalyptus* woodland ($13 < n < 362$) in 1972-73.

Increases in the numbers of applications in late summer and early autumn were clearly associated with opening rains for the subsequent winter (e.g. Fig. 6a). No obvious association between rainfall or temperature and the numbers of applications was apparent, however, in spring (e.g. Fig. 6b). Applications were severely restricted on Saturdays and Sundays and also on a public holiday (October 15). Data for these days should be ignored.

Discussion

O. moreleti is primarily nocturnal, as are other millipedes (Park *et al.* 1931, Park 1935, Cloudsley-Thompson 1951, Banerjee 1967). The environmental cues controlling this behaviour pattern are not known. Cloudsley-Thompson (1951) found that activity in two British species of millipede was primarily a response to light and darkness but was also stimulated by a fall in temperature. With two West African species, Cloudsley-Thompson (1951) demonstrated an endogenous rhythm which persisted for three weeks independent of fluctuating light and temperature. He considered that temperature fluctations are of primary importance in the initiation of activity rhythms in these West African species.

Table 3 Maturity of *Ommatoiulus moreleti* in different stadia on driveway

	Stadia								
	6	7	8	9	10	11	12	13	Total
(a) October 1986									
Females									
Without mature eggs		63	750	766	182	47	5		1813
With mature eggs									0
Males									
Juvenile		62	887	507	20				1476
Copulatory				5	19	3			27
Intercalary					10	1			11
(b) March 1987									
Females									
Without mature eggs	4	25	34	148	603	194	47	6	1061
With mature eggs				5	144	102	21	5	277
Males									
Juvenile		24	12	22	1				59
Copulatory			16	511	749	173	19		1468
Intercalary									0

Table 4 Age distributions and numbers of male and female *Ommatoiulus moreleti* on driveway between 12:00 and 14:00 h

	Stadia								
Date	89	10	11	12	13	14	Males	Females	Total
8 March 1987	1 21	60	18	5	1		57	49	106
20 March 1987	1 21	64	10	4			64	36	100
28 March 1987	1 19	57	23	11	1		81	31	112
7 April 1987	5 33	52	13	5	1		89	20	109
13 April 1987	1 21	59	20	3		1	78	27	105
27 April 1987	22	51	25	7			70	35	105
3 May 1987	20	38	36	4		2	74	26	100
12 May 1987	1 15	56	33	4			91	28	119
Total	10 172	437	178	43	3	3	604	252	856

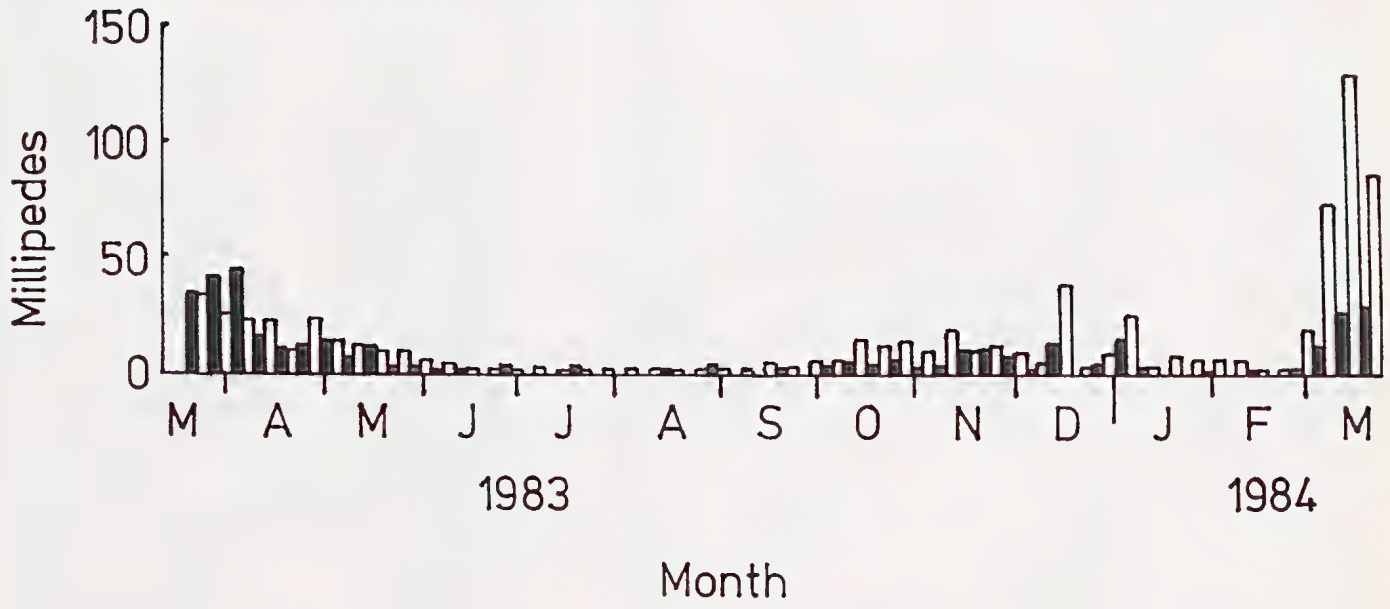

Fig 3. Numbers of males (shaded) and female (open) *Ommatoiulus moreleti* collected in pitfall traps in *Eucalyptus* woodland in 1983-84.

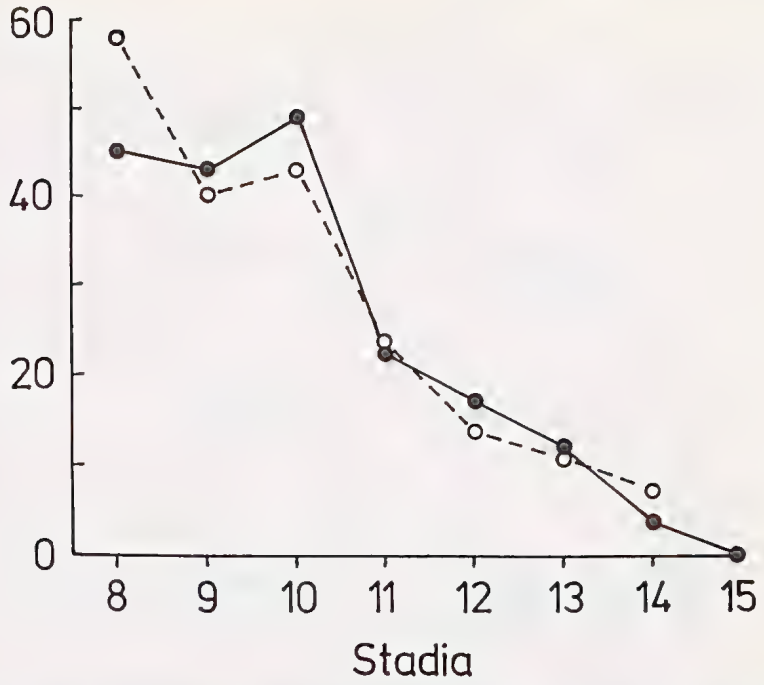

Fig 4. Percentages of males in different stadia of *Ommatoiulus moreleti* collected in pitfall traps in *Eucalyptus* woodland in 1972-73 (●) and 1983-84 (o) ($14 < n < 440$).

In the woodland and on the driveway, the proportion of males in the active *O. moreleti* population was lowest in late summer and highest in autumn. Similar patterns have been observed in grassland at Bridgewater and in shrubland in Portugal (Baker 1976,1984). Copulatory males, which are common in the soil and leaf litter in late summer and autumn (Baker 1978b,1984), are less able to survive exposure to high temperatures and low humidities than females (Baker 1980). Perhaps the scarcity of active males relative to females in late summer and early autumn reflects this differnece in climatic tolerance.

The decrease in sex ratio with increased stadial age in the *O. moreleti* trapped in the woodland probably reflects increasingly fewer males in older stadia rather than differences in the relative activity of the sexes. Baker (1978c) sampled leaf litter in the woodland and demonstrated lower survivorship of males compared with females through the old stadia. The decrease in sex ratio with increased stadial age observed in the driveway collections may also reflect differential survivorship of the sexes. However, the very large bias in favour of males in stadium 9 in autumn does suggest a difference in the behaviour of the sexes. Males and females are equally

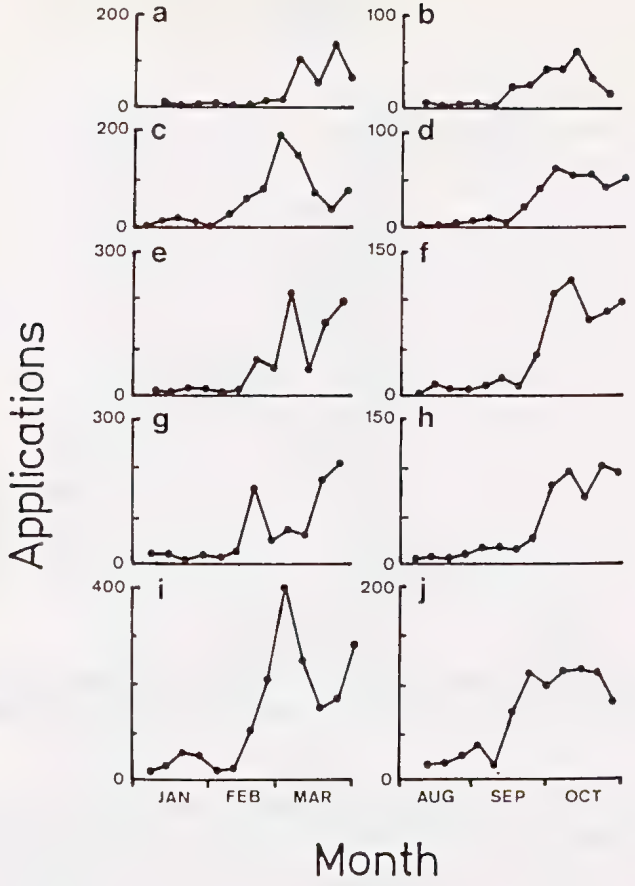

Fig 5. Numbers of applications to the District Council of Stirling for pesticide per week in 1975 (a,b), 1976 (c,d), 1977 (e,f), 1978 (g,h) and 1979 (i,j).

abundant in this stadium in leaf litter (Baker 1978b). Few females in stadium 9 possess mature eggs (Baker 1976, 1978b,c); the males collected on the driveway in stadium 9 were mostly copulatory adults. Differences in the maturity of the sexes within stadium 9 could be responsible for the different levels of activity observed.

Occasionally, large numbers of *O. moreleti* can be seen active during the day (Baker 1979b). Whilst Baker (1984) reported a predominance of females amongst active millipedes collected during the day in autumn in

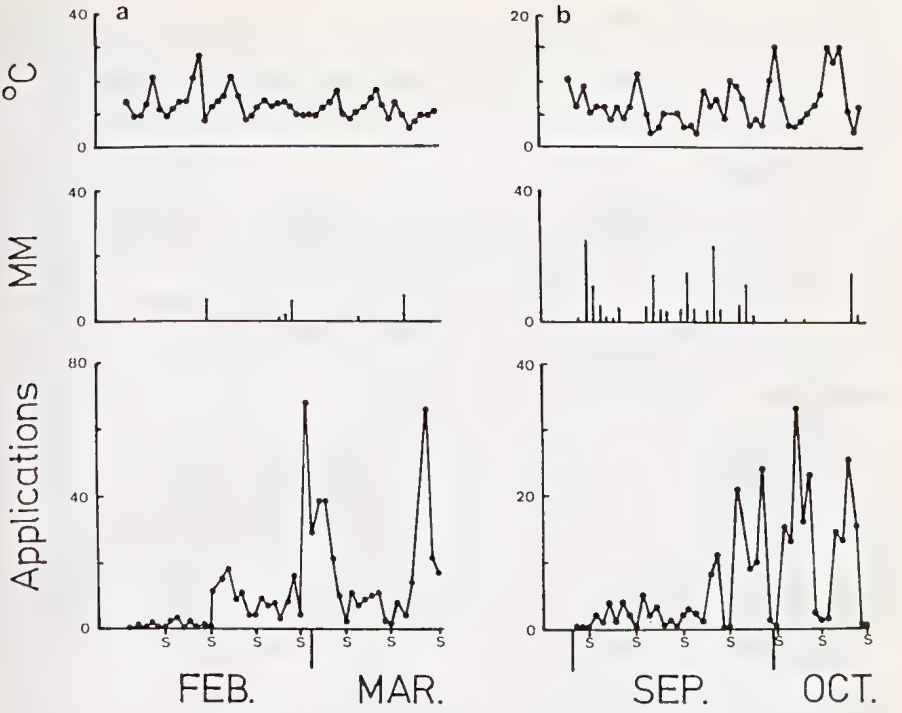

Fig 6. Daily applications to the District Council of Stirling for pesticide, rainfalls (mm) and minimum temperature (°C) in February and March 1977 (a) and September and October 1978 (b). Sundays are indicated (S).

a shrubland in Portugal, this was not observed around houses in South Australia where males were consistently more common than females. November 1981, when the observations were made in Portugal, was abnormally hot and dry (Baker 1984). It is possible that this extreme weather restricted the male millipedes to nocturnal activity far more than it did the more tolerant females.

The autumn eruption of active *O. moreleti* in residential areas is clearly associated with the onset of winter rains, as has been found in grasslands and woodlands (Baker 1979b). The activity of *O. moreleti* when conditions are moist in grasslands and woodlands is positively correlated with temperature (Baker 1979b). The lack of any obvious relationship between the sudden increase in numbers of applications for pesticide in residential areas in spring and prevailing temperature may simply reflect the crudeness of this estimate of millipede activity or ignorance of the

cumulative effect on activity of temperatures above a certain threshold (day-degrees). Alternatively, the primary stimulus for the spring eruption in activity may be something other than increased temperature (e.g. increased photoperiod). This topic deserves further attention.

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